# The eCraft2Learn project in 1st EPAL KORYDALLOS: integrating a FabLab in the school curriculum

**Konstantinos Asimakopoulos[1], Emmanouil Zoulias[2], Ioannis Saranteas[1], Ioannis Makaris[1], Georgia Sandali[1], Thomais Spiliou[1]**
kostasasimakopoulos@gmail.com, ezoulias@teemail.gr
[1] 1st EPAL KORYDALLOS, Piraeus, Greece
[2] Edumotiva, Sparta, Greece

## Abstract

Digital technology is radically changing the way people work in industry, finance, services, media and commerce. At the same time, schools are in difficulty to promote this knowledge due to the lack of the pedagogical models on how to apply new technology into teaching in a meaningful way. This work is a part of the implementation in formal education of a Horizon 2020 project called eCraft2Learn. The 1st EPAL KORYDALLOS implemented a part of the project in a FabLab in its facilities. In this work the methodology that was applied is based on, the Constructivist learning by making methodology that is strongly related to the do-it-yourself (DIY) philosophy. The main goal, for twenty-nine students, was to come up with solutions in engineering problems reinforcing personalised learning and teaching in science, technology, engineering, arts and math (STEAM) education.

**Keywords:** Digital Fabrication, eCraft2Learn, FabLab, constructionism, STEAM

## Introduction

Digital technology is radically changing the way people work in industry, finance, services, media and commerce (Bottino, Chioccariello, 2015) and also it is introducing the need for changes in the landscape of education and training. This fact has been exemplified in the report of the European Commission (2013). In reality, most of the technologies could serve education and learning in a better way to support the 21st century skills that are considered essential in our rapidly evolving employment landscape, such as creativity, entrepreneurship, critical thinking, collaboration skills, computational fluency, and so forth (Dede, 2010).

## Aim and objectives

This work is a part of the implementation in formal education of a Horizon 2020 project called eCraft2Learn (https://project.ecraft2learn.eu/) which has a three-fold focus interrelated within the pedagogical, technical and business objectives. The distinction between the three categories is therefore meant as a guiding structure, as the pedagogical objectives have technological development implications and business outcomes. All above mentioned objectives are closely related to the framework of a modern vocational school (Hillier, 2009).
The specific objectives for the pilot in 1st EPAL KORYDALLOS focused on developing a different approach to STEAM education, where the schooling of concepts is supplemented by crafts-based activities for making computer-supported artefacts in the context of STEAM education. The expected objective here is the promotion of hard and soft skills through making (problem solving, teamwork, persistence etc.). This achieved by ensuring a pedagogical practicability of learning designs by using advance technological development, relying on a participatory design approach. In addition to that the development and

integration of an eCraft2Learn curriculum into formal education reality promoting the STEAM idea in education, natural sciences and art subjects.

## Methodology

The eCraft2Learn methodology is based on the premises of learning by making. Learning by making methodology applications have their roots on the Constructivist theory of knowledge and the Constructionist educational theory. Constructivism is based on the proposition that knowledge is generated from the interplay between ideas and experience (Piaget 1976). Constructionism as an educational theory is inspired by the Constructivist ideas of learning. Hence Constructionism argues that learning is most effective when people are involved in the making of tangible objects in the real world (Papert, 1987). In this work the methodology that was applied is based on, the Constructivist learning by making methodology is strongly related to the do-it-yourself (DIY) philosophy, which stands for learning that goes beyond knowledge acquisition and aims to support future generations of empowered citizens (Meyer and Fourie, 2015).

The eCraft2Learn project deploy a craft- and project-based methodology, a combination of the inquiry-based learning with design thinking through the use of DIY and 3D printing technologies in order to enhance the pedagogical outcomes of the individually applied inquiry-based and design thinking methods. The craft- and project-based methodology involves the following processes stages that described in eCraft2Learn project website https://project.ecraft2learn.eu/project-overview/ .

Stage 1: Ideation through world exploration – in order to find out what kind of challenge they or someone else is facing in their daily life. The students could explore the world physical (e.g., taking pictures, exploring situations outside the classroom, etc.) or virtually (e.g., through online support community discussion) and then decide what their challenge will be. This process can also be guided by the STEAM coach.

Stage 2: Planning. Once the challenge has been defined, the students will start to collect information to make a project plan – they could get feedback from the STEAM coach on their project plan and also on the roles for group members.

Stage 3: Creation. In this stage the students embark on the co-design and co-creation of their computer-supported artefact solutions through the application of DIY technologies. Visualisation and simulation of the designs are also an important parts of this stage.

Stage 4: Programming. Once the computer-supported artefacts are built, the students will define suitable scripts (high-level programming language) for the functioning of their artefacts. Software debugging and integrated SW/HW simulation are two other parts of this stage.

Stage 5: Sharing. In order to enhance motivation, the students will be encouraged to share and showcase their projects and implementation ideas. This will be done through the open (online) community or through eCraft2Learn dissemination events. In return, they will receive feedback from artists, designers, engineers worldwide. Students will also participate on the eCraft3Learn dissemination events, where they will showcase their projects to the community in general.

## Integration of the eCraft2Learn pilots in the school curriculum

The 1st EPAL KORYDALLOS constitutes one of the largest vocational upper secondary school of the Attica prefecture. It comprises a wide range of vocational sectors (Information Technology, Economic and Management Services, Mechanical, Electrical-Electronics and

Automations, Medical, Graphic Arts) supported by the 6th EK PEIRAIA, the laboratory center of the school. Both schools belong to Technical Vocational Education and Training (TVET) of the formal education system of Greece. The 1st EPAL KORYDALLOS offers a 4th or a 5th level of EQF system certification after the students' graduation.

The 1st EPAL KORYDALLOS and the 6th EK PEIRAIA (Lab Center) participated in the implementation phase of eCraft2Learn project by running educational activities in its facilities. The implementation period lasted a total of 12 weeks (15/11/2017 – 28/02/2018) and it included educational activities for 2-3 hours per week, as an extracurricular program but embedded into the school program. All related workshops took place in a FabLab in our Laboratory Center which was created by the eCraft2Learn project and provided all the necessary equipment in order to complete the experiments. The course introduced a focus on design process, integrating digital fabrication and design thinking to create artefacts.

Nine teachers with minor or no previous experience in FabLab were trained to run the project in a five-day long seminar from 16/09/2017 to 14/10/2017 that took place in the Fab Lab of 6th EK PEIRAIA, Athens (Greece). A total of twenty-nine students participated in the program realisation, two of which were girls and were recruited, without exclusions, from Information Technology and Electricity educational sections of the eleventh grade and six teachers ( Table 1).

**Table 1. Students and Teachers of the 1st EPAL Korydallos**

| Educational Section | Students | Teachers |
|---|---|---|
| **Electrical** | **15** | **3** |
| **Information Tech** | **14** | **3** |

The main research question is how a public school could implement fab-learning pedagogy in the teaching of engineering activities within the current curriculum. Thus, the two groups of students were formatted by all students that the two classes had with no exclusions. We embedded the activities of the program into the school curriculum taking care of having every time the appropriate number of teachers without annoying the program of the school. It was crucial to examine the benefits and drawbacks of FabLab workshops according to the pedagogical and technical objectives of the program.

Prior to the start of the activities, students completed questionnaires on their experience in technological fabrication and their relationship and school performance in mathematics, science and technology. After completing the activities, they completed corresponding questionnaires in order to investigate and note the change in their attitudes, perceptions and skills.

During the implementation, one of the teachers involved took on the role of observer. He observed and recorded students' attitudes about teamwork, spirit of co-operation and mutual assistance, as well as managing problem-solving and achieving goals. Similar observations and notes were also made for the teachers involved in the activities. Note that teachers were alternated as observers, so that all the teachers involved were both observers and observed during the workshop.

Also note that before and after the workshop, the teachers involved completed as well questionnaires concerning their experience on the Fab-Learning methodology, managing technological problem-solving and achieving goals working on an unknown field which in addition has objective difficulties. The same questionnaires were also used for the teachers' role as instructors and learners at the same time with their students.

Finally, both students and teachers were interviewed to capture their experience of participating in the project.

## Activities

The workshops were based on the Fab-learning concepts that are considered to be an appropriate educational platform. Each activity has been designed taking into account two primary guidelines. Firstly, the fact that no prior knowledge in Fab- learning was required from the students in order to successfully complete it and secondly, the activities were designed on hands-on learning. The main goal was for students to come up with solutions in engineering problems reinforcing personalised learning and teaching in science, technology, engineering, arts and math (STEAM) education.

These were key features of the eCraft2Learn educational approach in order to trigger students' interest in the learning process. Students in Technical Vocational Education and Training (TVET) complain that they have difficulties to overcome because of lack of knowledge in mathematics and science. This kind of difficulty stands as a barrier to their future academic success. Due to the fact that the project based on digital fabrication and making technologies for creating computer-supported artefacts, students had the opportunity to approach abstract ideas of mathematics and science through tasks in a meaningful and concrete engineering environment that allowed them to come across concepts in mathematics and science. The following subsections provide a short description of the activities that were implemented in the two classes mentioned above.

### *Getting familiar with Arduino programming environment and visual block programming tools*

In three introductory lessons the students got familiar with Arduino programming environment and visual block programming tools. First of all they identified the basic components of the hardware material (Raspberry Pi and Arduino Uno), constructed a computer unit, browsed the web using the Raspberry Pi and introduced to programming. In particular, they connected their Arduino Uno unit to the Raspberry Pi board joining all the appropriate system peripherals such as SD card, mouse, keyboard, monitor, power cable and power supply. Consequently, they verified the connection settings through the Arduino IDE software menu, they tried to make the LED of the Arduino Uno board to blink at different rates based on sketches in the online IDE. Later they made their own circuits in order to control two LEDs. Finally, some of them made a construction representing traffic lights so they controlled three LEDs for cars and two LEDs for pedestrians (they used examples from the Arduino IDE environment to program the construction). Moreover, from the Arduino IDE, under Tools menu, invoked the Ardublock tool and tried to implement the same tasks using the visual block programming capabilities of this tool. Similarly, they made the Arduino to interactively communicate with the Snap4Arduino environment. In addition, they got familiar with Tinkercad drawing an electric circuit.

### *Using a potentiometer*

A potentiometer is a three-terminal resistor. If only two terminals are used, one end and the wiper, it acts as a variable resistor or rheostat. They are commonly used to control electrical devices. Students used Ardublock software tool and they tried to implement specific tasks with a potentiometer. They connected properly a potentiometer to the Arduino Uno board and assigned the consecutive readings into a variable visible on the monitor. Also, they made these values to be continuously updated on the scene place. They constructed an electric circuit that the led was controlled by the potentiometer. Furthermore, they used Snap4Arduino environment to make the same tasks.

### *Christmas Project*

Students tried to make a Christmas tree able to generate sounds / music or make LEDs on it to blink at different rates or make a RGB led to change colors. They investigated how to combine light or motion sensors with the Arduino Uno so as to capture actuation events. Not a specific scenario had to be followed in details by all participants' teams. So every team made its own construction and tried to apply its own ideas. Students had to use cardboard to make a Christmas tree (some of them constructed a festively decorated home) and glue on it light or motion sensors and LEDs. They also connected the artefact with an angle servo so as to make it move. In order to produce sounds, they used a pair of speakers connected to the output pins of the Arduino via "female" speaker jack. In order to generate music, they had to connect the speakers to the 3.5mm jack of the RPi3 board. Simple programs had to be implemented using the Snap4Arduino environment in order to make the above setup be functional.

### *The Light House Project*

In this workshop students a) constructed a lighthouse miniature, using paper/plastic bottles, having its light blinking at a specific rate and only at night (i.e. when external light is low) and b) tried to make a led to blink at different rates and inspect analog values to be captured using a simple photo resistor. Students connected their Arduino Uno unit to the Raspberry Pi board and verified the connection settings through the Arduino Software (IDE). They used the Ardublock tool and the Snap4Arduino tool trying to implement specific tasks by using the visual block programming capabilities of these tools.

### *The Sunflower Project*

In this workshop students a) tried to connect to the Arduino one or two photoresistor sensors and an angle servo (actuator) and understand how they work and b) sketched a sunflower on a paper using also chopsticks, straws and wire and they glued it on the angle servo. They also glued the two light sensor units so as to form an angle of 100o approximately. Finally, they wrote code so as to make the sunflower move to the left or to the right, depending on the two vertically opposed light sensor readings. They used the Snap4Arduino tool trying to implement the above tasks.

### *The Solar Vehicle Project*

A solar vehicle is an electric vehicle powered by direct solar energy. Solar vehicles depend on photovoltaic cells to convert sunlight into electricity to drive electric motors. This session was trying to tackle with the issues of motor driving through Arduino / Raspberry and of creating autonomous robotic artefacts. Students tried to make a robotic car able to move with solar energy. They tried to investigate how to combine motors and sensors with the Arduino Uno in order to move the robotic solar vehicle using the photovoltaic cells. Simple programs were implemented using the Ardublock environment in order to make the above setup be functional. They wrote code for a motor turning back and forth (and some of them for circular movement). One team experimented with a robotic car implementation with two motors. Another one wrote a code using a distance sensor. A third one had an excellent idea to construct a steering system in order to ensure that the wheels were pointing in the desired directions. Another one experimented with four motors and four wheels.

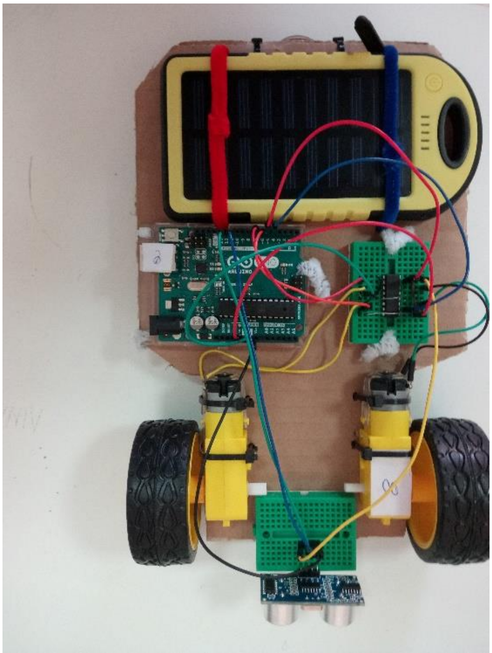

**Figure 1 Indicative solar vehicle car made by a student's team**

## Results

Digital technology has radically changed the way people work in industry, finance, services, media and commerce and has urged necessary corresponding changes in educational systems. However there is a lack of progress in the education system. For instance, the idea of FabLab does not run to the Greek school curriculum although many years ago researchers at MIT (Gershenfeld, 2007; Mikhak et al., 2002) made strong arguments about the use of FabLabs in the educational system and managed to make it a global movement. In our school we try to overcome these barriers changing the narrow perception that technologies are used in education and training today in order to support the 21st-century learning skills.

The students that participated in the program had a very positive attitude throughout the twelve weeks of the eCraft2Learn Project. Not only was the new content that make them happier but the idea of the FabLab which combines digital fabrication and hands-on technologies for creating computer-supported artefacts. We can conclude that they experienced high enthusiasm, high participation and a real sense of achievement. In general, they achieved successfully working in groups and cooperating with their peers, helping or assisting each other in difficulties, advising their classmates to solve and overcome problems. They, also, discovered the importance and the power of "learning how to learn", which would motivate them in the future to discover and explore. Every time they enjoyed the work with physical materials and after the brainstorming they constructed interesting artefacts. Students from the information tech section understood the necessity of electric circuits and on the other hand students of electrical section thought about how programming could help their work. On the other hand, students had difficulties with programming and found it difficult to communicate and share their ideas due to a lack of time.

The teachers also reported positive feedback from the project. They had the opportunity to work exclusively with students who generally have learning difficulties, inside the school hours but in a FabLab and with a new Fab-learning methodology. Furthermore, they were trained to teach a new subject that was not included in their regular syllabus and were not familiar with it beforehand. It was very fulfilling for the educators, to see the positive effects this teaching approach had on their students. Our FabLab is equipped with various electronic and computational devices (Arduino Uno & Rasberry Pi), software for 3D mechanical design and modeling (Tinkercad), simulations, circuit boards, programming tools, a 3d printing machine, internet access for communication and information retrieval purposes, and documentation. On the other hand a typical school science lab is designed for rigorous, disciplined, and scripted experiences. Undoubtedly, teachers feel anxious working in a new environment such as a FabLab environment because it is easy to make mistakes when trying to do things with no previous experience. They need to prepare for uncertainty and the new role that they have is that of the facilitator. So teachers must rethink their role in a FabLab in relation with the new role of students. Sometimes, they have to give them time to go through problems by themselves, to encourage them to solve problems by themselves and to be independent of the teacher's support. However, we observed that many times, especially with programming, students felt frustrated and gave up learning. Teachers needed to encourage them and provided successive levels of temporary support.

Many difficulties emerged during the course. We had some technical problems with the equipment and the network. For example, because of the slow Internet connection of the laboratory, students did not work with Tinkercad. Only one team managed to make its model. Sometimes there was a problem to connect the Arduino with the Snap4Arduino and the Ardublock environment. Moreover we had some problems with the connection of a motion sensor to the Arduino in order to work reliably. Another problem was the lack of time. Students needed more time in order to complete and share their work. Furthermore, students spent much time to the phase of "create" in relation with other phases. As a result they did not use many digital materials. On the other side, the three programming tools (Arduino IDE, Ardublock and Snap4Arduino) created confusion in students' minds. They have to get familiar with programming tools and need to have more time to run their projects.

In conclusion, a digital fabrication lab, which merges computation, tinkering and engineering combines the technological skills with the computational thinking. The above educational activities were based on the principles of the constructionism as a process of learning by making and used the Arduino Uno platform within the eCraft2Learn Project. We need authentic and problem-based learning activities, teachers who adopt the role of a facilitator and pupils who engage actively in the learning process. We can say that the twelve-week course was very promising and both the students and the teachers are looking forward to the second course of the program. Digital fabrication is a new chapter in the formal education system.

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